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**NASA TECHNICAL  
MEMORANDUM**

**NASA TM X- 73954**

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**A SEAT CUSHION TO PROVIDE  
REALISTIC ACCELERATION CUES FOR AIRCRAFT SIMULATORS**

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(NASA-TM-X-73954) A SEAT CUSHION TO PROVIDE  
REALISTIC ACCELERATION CUES FOR AIRCRAFT  
SIMULATORS (NASA) 22 p HC \$3.50 CSCI 14B

N76-35189

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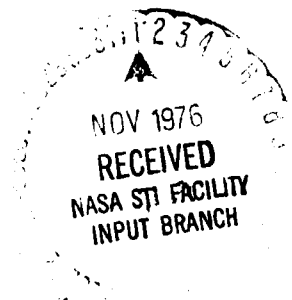
**SEPTEMBER 1976**

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National Aeronautics and  
Space Administration

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1. Report No. NASA TM X-73954		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle A Seat Cushion to Provide Realistic Acceleration Cues for Aircraft Simulators				5. Report Date September 1976	
				6. Performing Organization Code 1132	
7. Author(s) Billy R. Ashworth				8. Performing Organization Report No.	
9. Performing Organization Name and Address NASA Langley Research Center Hampton, Virginia 23666				10. Work Unit No. 504-09 -41-01	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546				13. Type of Report and Period Covered Technical Memorandum	
				14. Sponsoring Agency Code	
15. Supplementary Notes					
16. Abstract <p>A seat cushion to provide acceleration cues for aircraft simulator pilots has been built, performance tested, and evaluated in NASA Langley's Differential Maneuvering Simulator. The four cell seat, using a thin air cushion with highly responsive pressure control, attempts to reproduce the same events which occur in an aircraft seat under acceleration loading. The pressure controller provides seat cushion responses which are considered adequate for current high performance aircraft simulations. The initial tests of the seat cushions have resulted in excellent pilot opinion of the cushion's ability to provide realistic and useful cues to the simulator pilot.</p>					
17. Key Words (Suggested by Author(s)) Seat Cushion                      G Seat Simulators                      Kinesthetic Cues Acceleration Cues			18. Distribution Statement Unclassified Unlimited (STAR Category 05)		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 20	22. Price* \$3.25		

## SUMMARY

A seat cushion to provide acceleration cues for aircraft simulator pilots has been built, performance tested, and evaluated in NASA Langley's Differential Maneuvering Simulator. The four cell seat, using a thin air cushion with highly responsive pressure control, attempts to reproduce the same events which occur in an aircraft seat under acceleration loading. The pressure controller provides seat cushion responses which are considered adequate for current high performance aircraft simulations. The initial tests of the seat cushions have resulted in excellent pilot opinion of the cushion's ability to provide realistic and useful cues to the simulator pilot.

## INTRODUCTION

In the control of an aircraft, the kinesthetic cues or "seat-of-the-pants" feel provide important information to the pilot concerning the aircraft's dynamic state. Pilots sense such kinesthetic cues as buffet, control forces, and linear and angular accelerations. One of the most important of the acceleration cues is the normal acceleration. Under positive normal acceleration, the pilot is subjected to an increase in weight for each part of the body. This results in such things as the blood pooling in the lower portions of the body and a reduced blood flow to the head which eventually results in tunnel vision and blackout, (Reference 1). The increased body weight also causes increased pressure on the "seat-of-the-pants" as the seat cushion padding becomes fully compressed and no longer conforms to the pilot's buttocks. This causes a greater portion of the pilot's weight to be borne by the area around the tuberosities (the two bones which protrude furthest into the buttocks) and thus a change in the pressure distribution on the buttocks.

There are other acceleration cues such as heaviness in the extremities; however, the "seat-of-the-pants" feel seems to be one of the most noticeable. In view of this, a seat cushion was designed and built to reproduce these pilot sensations in an aircraft simulator. This paper describes the approach to the cushion design in order to duplicate the pilot seat sensations due to accelerations. The seat cushion pressure controller is described along with cushion responses which show the seat capable of following the commands with minimal hardware lag. Pilot opinions concerning the realism of the seat cue and its value as a performance aid are also included.

### Seat Cushion Design

The objective in building the simulator seat cushion is simply to reproduce as nearly as possible the same events which occur in the aircraft seat. In order to compress the seat padding as if the pilot weighed more, air with pressure control is used as the padding material with a non-compressible surface (wood) underneath the air cushion. The basic design is shown in Figure 1.

The seat is initially biased such that the air conforms to the pilot to support most of his weight as shown in Figure 2. The initial air pressure allows the two main support areas, the tuberosities, to touch the wood surface and thus begin to compress the flesh near these areas. Thus the bias adjusts the "firmness" of the seat. Then as accelerations increase (positive g) air is removed from the seat giving the effect of compressing the cushion material and causing more of the pilot's weight to be supported by the area around the tuberosities. However, some air is left in the seat to prevent the false cue of the seat falling away from the sides of the legs and buttocks. For negative g sufficient air is added to seat to remove all contact with the wood and thus uniformly support the body weight, without becoming firm due to too much air.

This manner of seat operation (i.e. reproducing the aircraft seat actions) automatically reproduces other related pilot events as raising or lowering the body which results in changing the eyepoint and the joint (hips and knees) angles.

The full seat design is shown in Figure 3. The air cushion is made of pliable rubber and has four air cells per seat and back cushion with individual pressure controllers for each of the eight cells. This allows differential control to "tilt" the seat pan for various cues. The air cushions are 2.54 cm (1 inch) thick to minimize "following" as the pilot shifts his weight and

increase response time by lowering the air volume required. The "following" occurs when the pilot moves in such a manner to remove a part of his buttock area from contact with the seat. The constant air pressure would cause the seat cell to "follow" the moving buttock area until the seat reaches the limit of its excursion capability. In this case the maximum "following" would be 2.54 cm (1 inch) or less.

### Hardware Response

It was considered important for the seat to follow the command with minimum time lag in order to be able to respond to the aircraft dynamics. It is also desired to closely match the seat response with the simulator's visual display response. The design of the seat requires a decrease in air pressure (and, consequently, more of the pilot's buttock area contacting the hard surface) for positive g; therefore, the removal of air from the seat is the most important and most difficult to achieve due to the low pressure differential. Figure 5 shows a bleed time (positive g) of 60 milliseconds and a pressurization time (decreasing g) of 45 milliseconds for a 50% step. Both positive and negative steps have settled to within 10% of the final value in 100 milliseconds. The sinusoidal responses show that a 75 millisecond time lag is obtained from 0-3 hz. A typical sinusoidal response is shown in Figure 6. The dynamic response data is summarized in Table 1. Figure 7 shows a linear relationship for input voltage versus final seat cell pressure. The figure also shows that the seat is not driven to zero pressure (differential) to prevent the false cue of the seat falling away from the sides of the legs and buttocks.



### Pressure Controller

The inherent design of the seat requires precise and responsive control of the air pressure in each cell. Therefore, the servo controller utilizes pressure feedback as shown in Figure 4. The air control valve used is a standard aircraft anti-g suit valve with the normal activating slug replaced by a motor which provides the linear actuation of the valve. The aircraft valve was chosen because it provides adequate pressurization time and, more importantly, adequate bleed time without the use of other devices such as booster relays which tend to degrade the pressurization time. The valve has a non-linear relationship between the input displacement and the output pressure, however, the pressure feedback provides linear response. The compensation is used to adjust the damping and bandwidth of the system.

### Initial Testing

A complete seat pan was installed in NASA Langley's Differential Maneuvering Simulator (DMS), Figures 8 and 9, which is described in Reference 2. The seat was initially set-up to be driven by normal acceleration only and the seat cells were subjectively scaled so that the two forward cells were always at 1/2 the pressure of the two rear cells. The normal acceleration drive signal was scaled for maximum g "feel" at +6g and 0g with the 1g neutral position biased to allow the pilot's tuberosities to just start to contact the hard surface as described earlier. This scaling was found to give good pilot sensitivity to small "g" increments while performing tracking tasks as well as good overall feel at the maximum g levels.

Initial studies were run in the DMS using a thoroughly validated F5-E as the test aircraft. NASA test pilots performed tracking tasks against three different maneuvers flown by one of the test pilots and stored on magnetic tape for computer playback. This provided repeatable tasks for the pilot's evaluation of their performance with and without the g-seat. The target maneuvers consisted of a 4g to 7g wind-up turn, a horizontal S, and a general air combat maneuvers task. Figure 10 shows the normal acceleration command and the pressure response of one of the four seat cushion cells during one of the "horizontal S" runs which is a series of bank to bank maneuvers. It can be seen that the cushion pressure follows the normal acceleration command very well during a near maximum aircraft performance pull-up from approximately 1.5g to greater than 6g (6g is scaled as the maximum cue). The seat also follows the approximately 1Hz oscillations which are again near maximum pilot/aircraft performance levels. The high frequency component shown on the pressure trace is due to the aircraft buffet moving the entire cockpit and causing the pilot to

bounce slightly on the seat.

#### CONCLUDING REMARKS

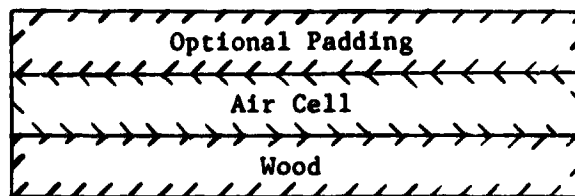
These initial studies have resulted in pilot opinions that the seat cushions provide excellent normal acceleration cues and add to the realism of the simulation. The pilots also feel that they are able to use the cues provided by the seat to improve their tracking performance. Therefore, it is recommended that effort be devoted to measuring pilot's performance during these tracking tasks in order to discriminate between tracking performance with and without the seat cushions.

#### REFERENCES

1. Singer, S. F.: PROGRESS IN THE ASTRONAUTICAL SCIENCES. Interscience Publishers, Inc., c.1962.
2. Ashworth, B. R.; and Kahlbaum, William M., Jr: DESCRIPTION AND PERFORMANCE OF THE LANGLEY DIFFERENTIAL MANEUVERING SIMULATOR. NASA TN D-7304, 1973.

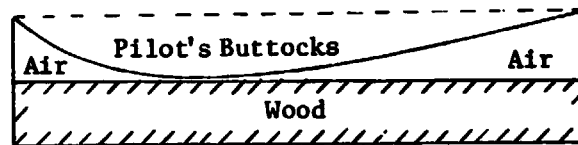
Command	Maximum Time Lag
50% Step	65 milliseconds
50% Sinusoid (0-3Hz)	75 milliseconds

**TABLE 1.- Seat Cushion Dynamic Response Characteristics**

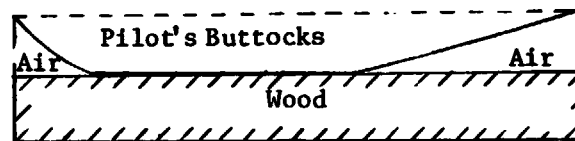


Cross Section

Figure 1.- Basic Seat Concept for One Cell



(a) Neutral - 1g Bias



(b) Positive g

Figure 2.- Seat Operation

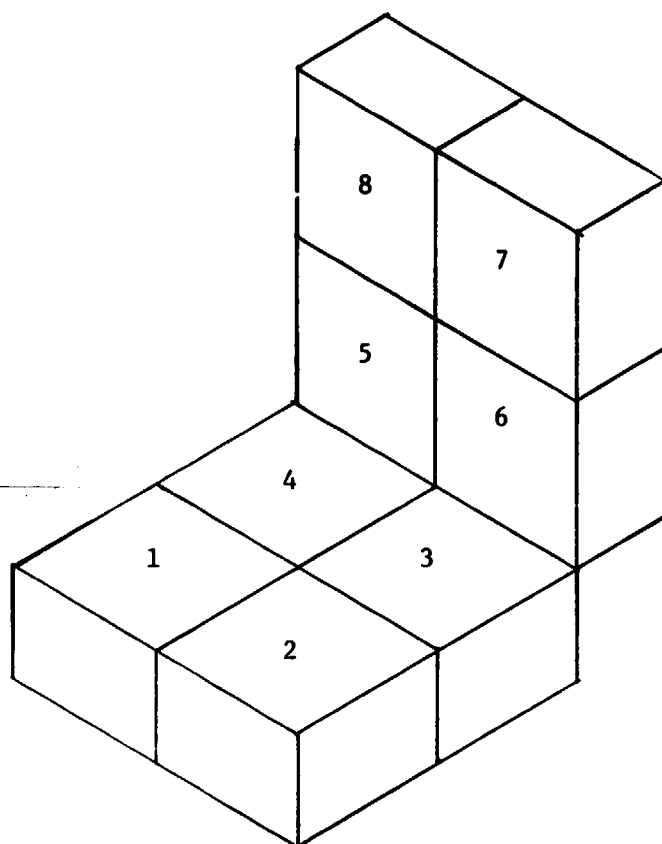


Figure 3.- Seat and Back Cushions (4-cell)



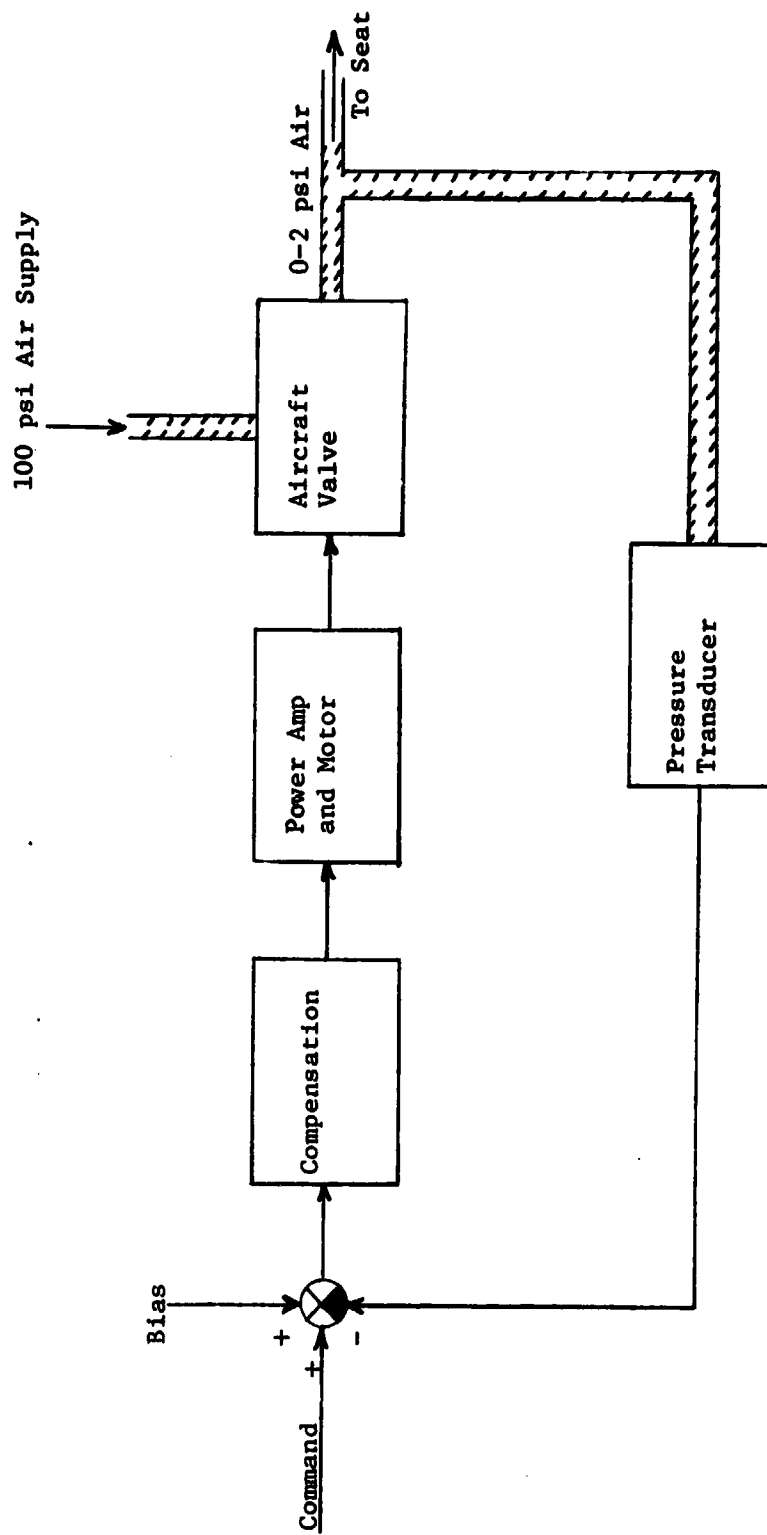


Figure 4.- Servo Controller for 1 Seat Compartment

Figure 5a.- Negative g Response

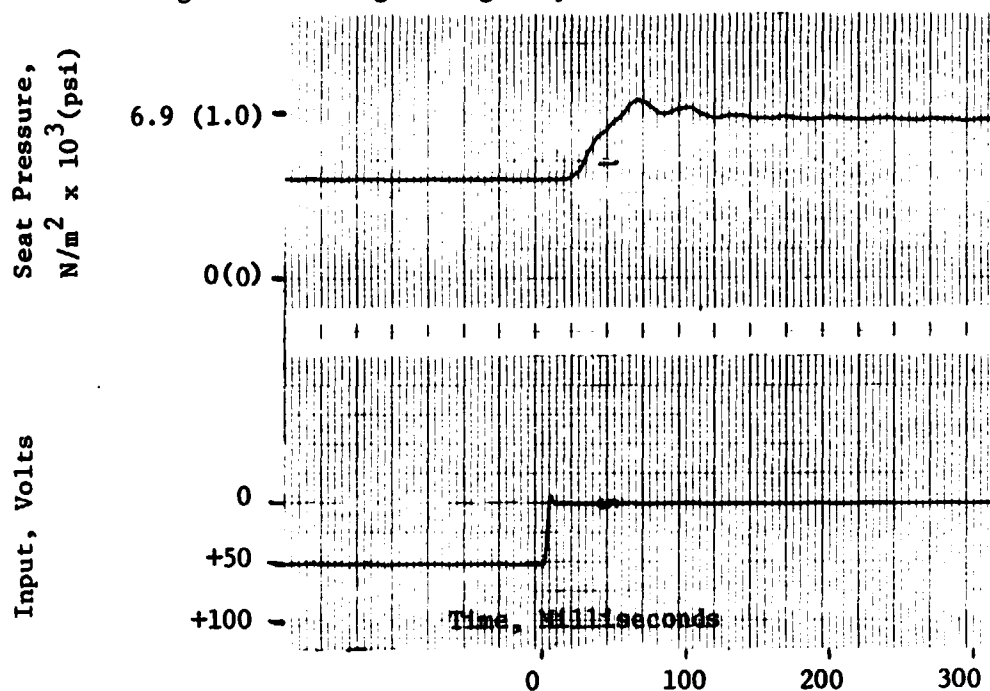


Figure 5b.- Positive g Response

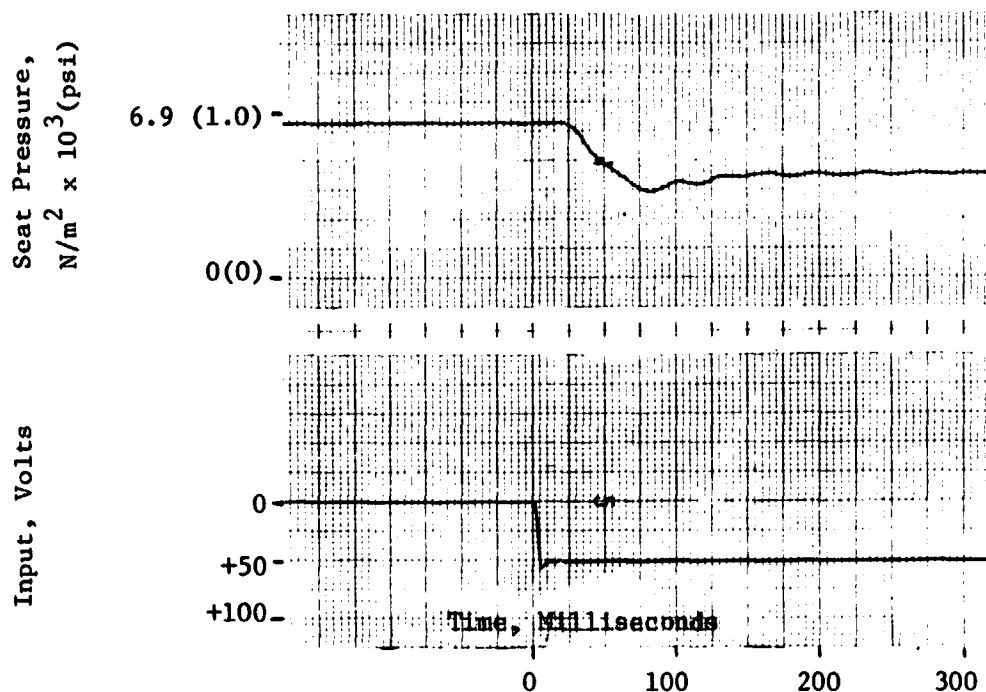


Figure 5.- G-Seat Step Response for 50% Step Input (1 cell)

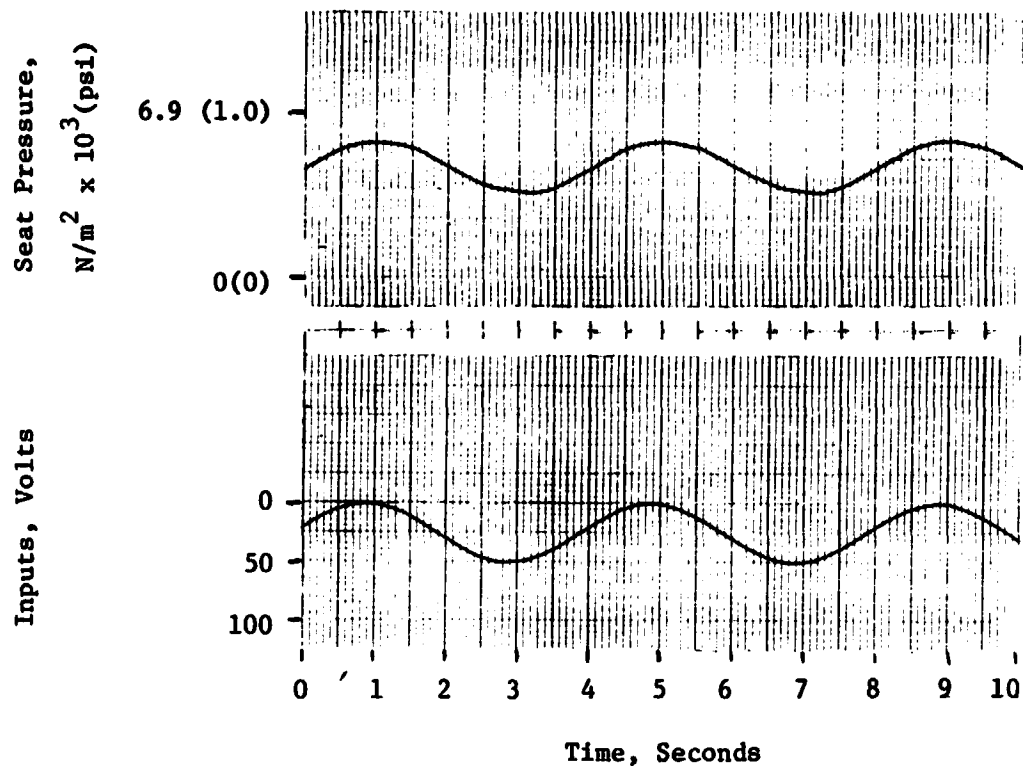
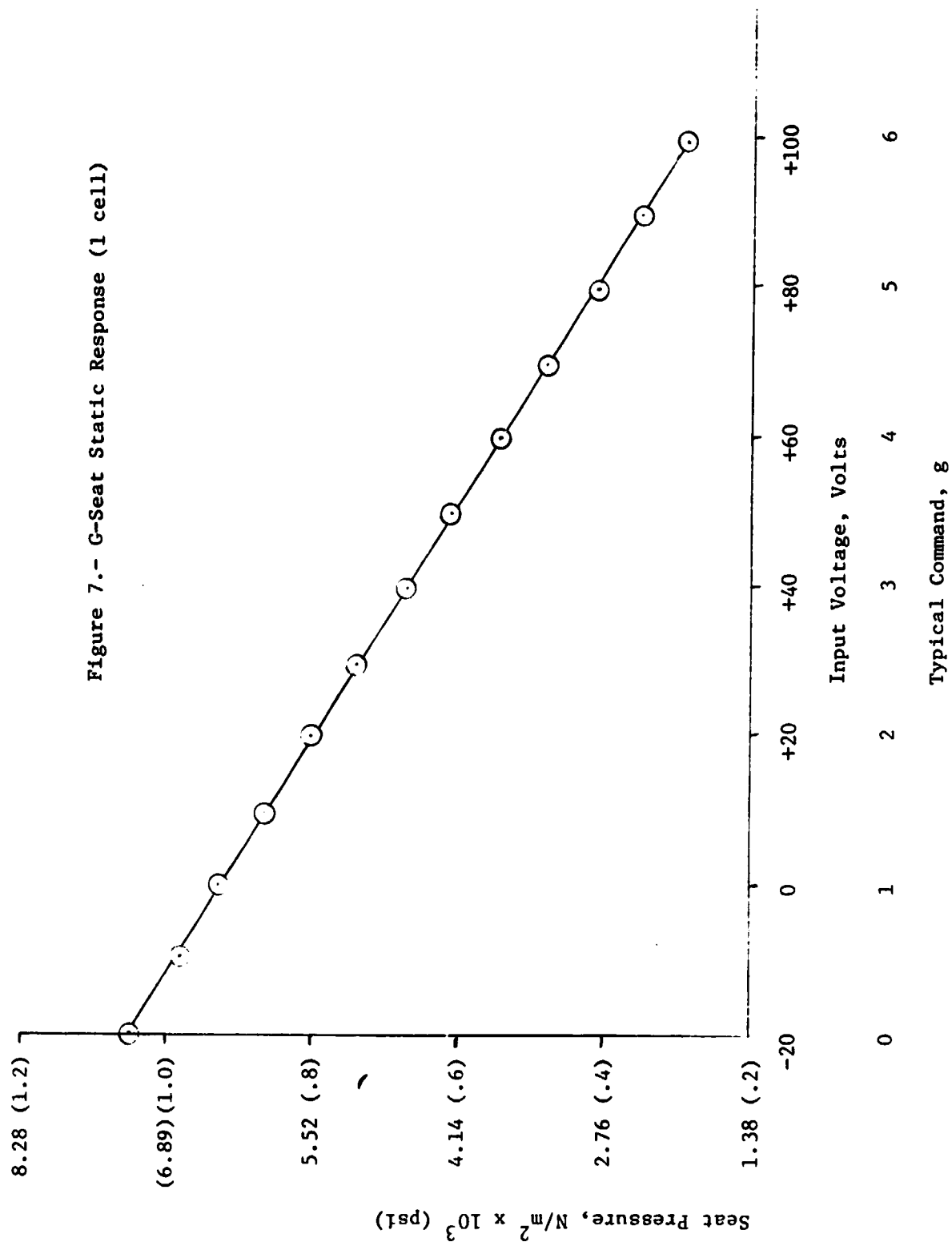
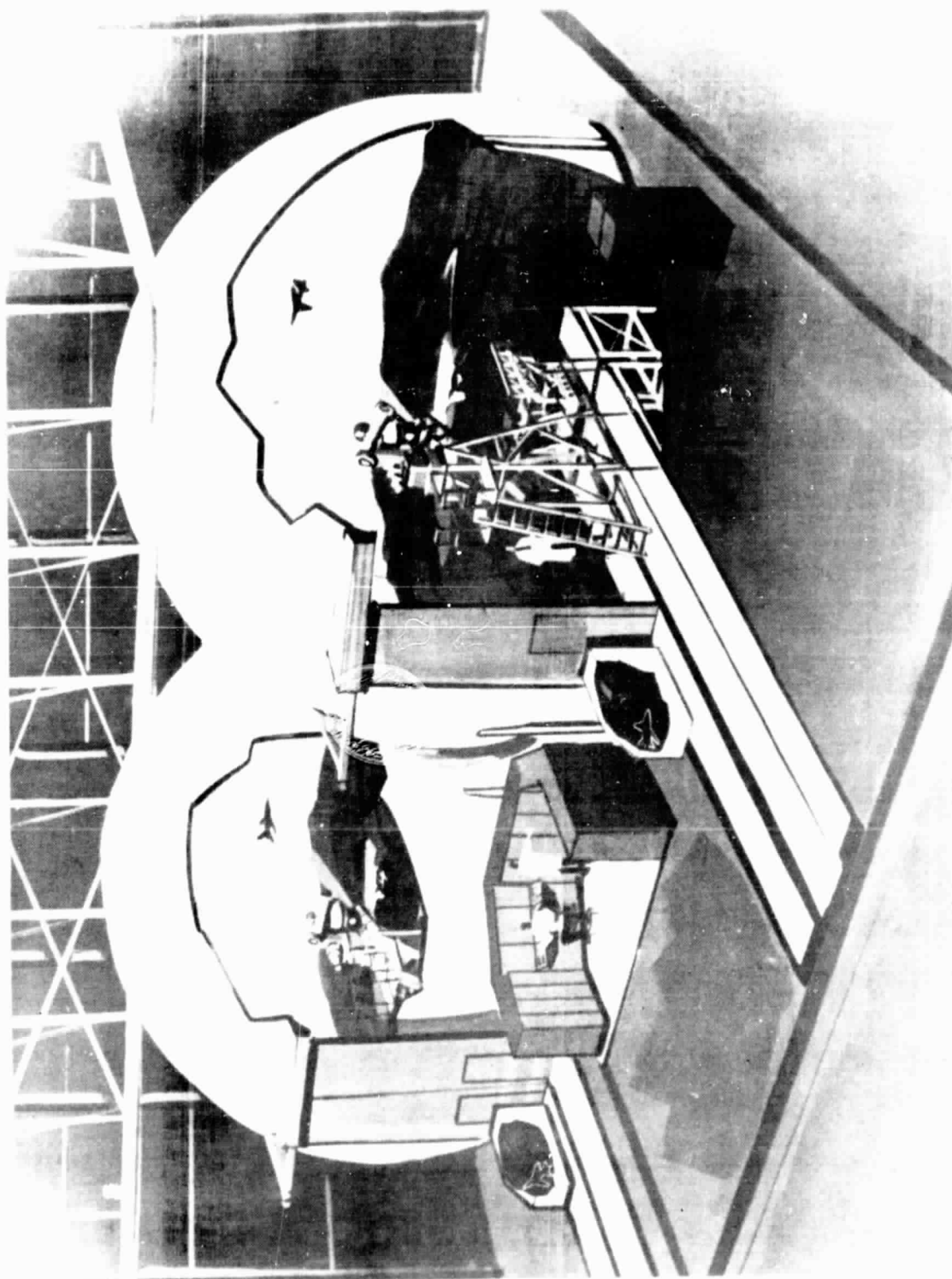


Figure 6.- Typical Sinusoidal Response (1 cell)





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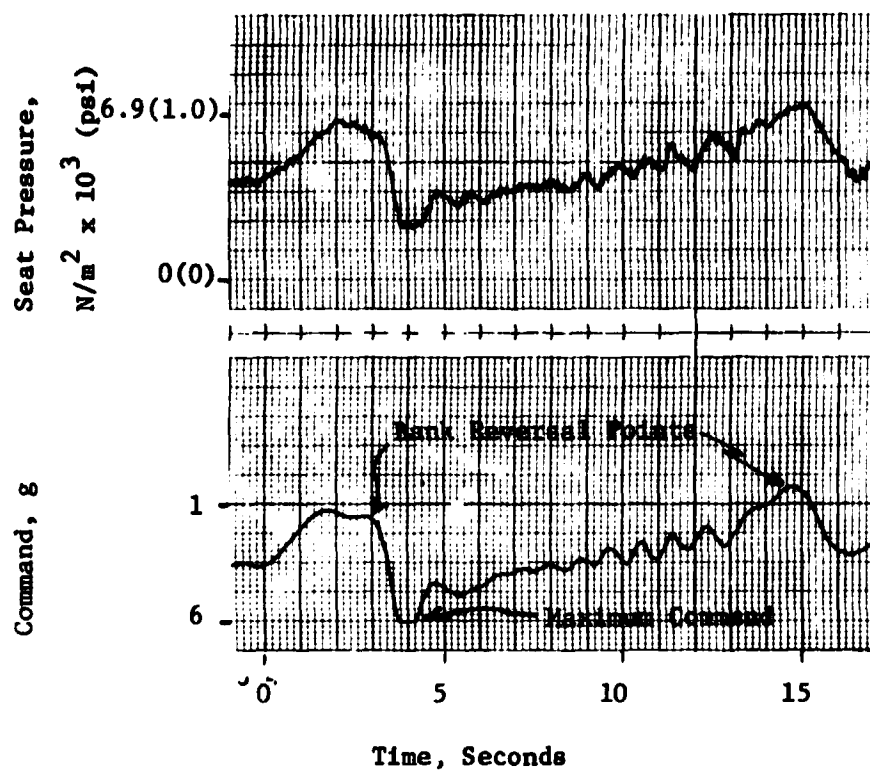


Figure 10.- Seat Response (1 cell) for "Horizontal S" Tracking Run